WEAR RESISTANCE OF DIFFERENT COMPOSITE MATERIALS USED WITH BONDED ORTHODONTIC RETAINERS: A LABORATORY STUDY

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ABSTRACT

Wear Resistance of Different Composite Materials used with Bonded Orthodontic Retainers: A Laboratory Study

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Background: The attritional wear of orthodontic retainer bonding materials limits the service time of the fixed orthodontic retainers.

Aim: To investigate wear resistance of different types of bonded retainer composites.

Materials and Methods: Four different composite resins (Filtek Z350, Filtek Supreme Ultra, Transbond XT and Ketac Nano;3MEspe, Seefeld, Germany) were subjected to three-body abrasion test. Twenty specimens of each composite type were prepared by bonding a segment of twist flex wire (size 0.0195”) into blastic upper right and left central incisors. Each specimen was tested under dual axis chewing simulator (Willytec, Munich, Germany) with 49N for 200,000 loading cycles with addition of abrasive media that was used to submerge each specimen to simulate abrasion caused by food particles. The abrasive was media prepared by grinding 30 g of millet-seed and 120 g of white rice and mixed with 275 ml of distilled water. Computer-aided 3D scanner (Ceramill Map 200+, Amanngirrbach, Koblach, Austria) was used to 3D scan each specimen before and after chewing simulator three-body abrasion test. The 3D scans were analyzed by Blender.app PC software, 2.81a version (Blender Foundation, Amsterdam, The Netherlands) to evaluate the volume loss of each composite by calculating the volume difference in mm^3 before and after the chewing test. Finally, data were statistically analyzed using ANOVA and the post-hoc Tukey test.

Results: Statistical difference in wear resistance was found between all the groups. The highest wear resistance was found with Filtek Z350 followed by Transbond XT. Lower values corresponded to Filtek Supreme Ultra while the lowest values were related to Ketac Nano.

Conclusion: Wear resistance values were significantly higher with higher composite filler content. The lowest wear resistance value was found with the least filler content composite.

DEDICATION

I am thankful to Almighty Allah for his generous blessings in life which empowered my will to accomplish my thesis.

DECLARATION

I hereby declare that the dissertation entitled "*WEAR RESISTANCE OF DIFFERENT COMPOSITE MATERIALS USED WITH BONDED ORTHODONTIC RETAINERS: A LABORATORY STUDY*" submitted by me for the partial fulfillment of the Master of Science in Orthodontics at the Hamdan Bin Mohammed College of Dental Medicine (HBMCDM), Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU) is my original work under the direct supervision of Associate Professor Ahmed Ghoneima and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, or any other title in this university or any other institution.

Name:

Signature:

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1. INTRODUCTION

Orthodontic retention is an essential stage that is performed at the end of the active phase of orthodontic treatment. This stage aims to minimize the unwanted tooth movement and to maintain the teeth in their final corrected positions after removal of the orthodontic appliance. Maintaining the teeth and the dental arches in their final positions following orthodontic treatment is one of the most difficult stages in orthodontics. Changes produced by growth together with the soft tissue pressure of the gingival and periodontal tissues may challenge the long-term stability (1).

Orthodontic retainers are commonly used after completing orthodontic treatment, and they are indicated to prevent post-orthodontic treatment changes of the teeth (2). Orthodontic retainers are required to be kept in place for a long time, given that they don't cause adverse effects on the periodontal condition (3).

Maintaining stable treatment outcome is a challenging task for orthodontic treatment providers. Reductions in arch length and width are frequently seen with aging, thus producing significant irregularity and crowding at the front teeth (4). There is general agreement on the fact that post-treatment retention protocol should be followed as long as teeth alignment is needed. Practitioners aim to avoid undesired consequences related to the post-orthodontic treatment changes by using retainers for long period (5).

Permanent retainers have long been advocated for the long-term stability of the mandibular anterior teeth. As the introduction of acid etched dental bonding methods in 1973, Knierim suggested lower cuspid to cuspid direct fixed retainers. And in 1974 Wolfson et al. described the usage of a stainless steel retainer wire with a welded mesh that is bonded to the lingual surface of the mandibular canines (6).

More stable results after orthodontic treatment can be obtained if treatment outcomes are achieved with a stable occlusion. Overcorrection has been reported in several literature as a method for obtaining stable treatment outcomes. The concept of overcorrection is particularly recommended in cases with severe crowding or severely rotated teeth (7).

2. LITERATURE REVIEW

2.1 Relapse

Relapse is the tooth movement or free movement of the teeth toward their original position following cessation of orthodontic force after active orthodontic treatment. Achieving appropriate treatment outcomes with proper occlusion, overjet, overbite, etc. reduce the risk of post-treatment changes. In the 1960s an experimental study presented by Reitan revealed that the reorganization of the periodontal ligament (PDL) near to the alveolar bone differs from the tension and pressure sides. At the tension side, orthodontic forces generated by the appliance are going to be resisted by the stretched periodontal fibers. Whereas at the pressure side, hyalinization of periodontal fibrous tissues and undermining bone resorption happens (8).

2.2 Types of Relapse

Reorganization of the bone and periodontal fibers in the apical and middle thirds take place following the retention phase. However, displacement of the supra crystal periodontal ligament fiber can still be evident even after 232 days. It was stated by Reitan that fiberotomy can cause reorganization of the supra alveolar periodontal fibers to happen during the first twelve months (8) .Van Leeuwen et al. explained that orthodontic treatment related relapse can be considered associated with PDL, alveolar bone and gingival tissue remodeling. This type of relapse often occurs immediately after orthodontic translation teeth movement and it shouldn’t be mixed with long term post orthodontic changes. Maltha and Von den Hoff revealed that after active teeth movement 30 to 90 percent of the teeth experience immediate relapse (7).

There is variation among slow and fast types of relapse. The fast type of relapse happens during the periodontal ligaments remodeling. However, the slow relapse is hard to be distinguished from the craniofacial changes that take place with aging and natural growth changes. Morphology changes of the craniofacial bones and jaws can alter the dentition. For example, reduction of arch length, depth, and perimeter of both maxillary and mandibular arches occur with aging (9).

Natural growth cause dental changes to happen on long periods of time and it is usually occurring with the previous factors (10). To overcome the elasticity of periodontal and gingival tissues with their fibers recoil that cause relapse and the variable unpredictable dental alterations caused by the biological changes, retention phase is very important and is mandatory for the orthodontic treatment success. The retention phase should also allow for the periodontal tissues and fibers and alveolar bone remodeling (11).

2.3 Causes of Relapse

Even though there are numerous reasons involved in post-orthodontic treatment changes, 3 major reasons can be briefed: the need for an adequate period of time for reorganization of periodontal and gingival tissues, teeth positioning out of the balanced position after orthodontic therapy, and changes caused by growth (12). Several earlier researches revealed high-level of relapse rates of the lower anterior teeth following orthodontic therapy (13). Post-orthodontic treatment changes can be evident if the following tooth movements were done during the treatment:

1- Excessive proclination of the lower incisors.

Proclination tends to place incisors outside the neutral zone subjecting them to imbalanced forces that potentially can cause malalignment.

2- Cases with expansion.

Expansion is another way of placing teeth in unfavorable position in terms of placing the teeth in areas with unequal forces that tend to cause relapse especially in cases where there is no pre-treatment crossbite.

3- Closure of spaced dentition.

Spaces closure - especially if large - causes the interdental soft tissue in the gum to crumple which can lead to post-treatment spaces reopening.

4- Significant derotation movements.

Derotation movements cause transseptal fibers and other gingival fibers to stretch. Recoil of stretched gingival fibers has the potential to cause relapse.

5- Significantly changing of the mandibular inter-canine dimension.

Increasing inter-canine width has been reported in the literature as unstable orthodontic movement that often leads to post-treatment relapse (14).

The main reason behind unstable orthodontic treatment result can be because many months is required for the reorganization of the tissues around the teeth. Moreover, tongue, lips, and cheeks pressure simultaneously with growth might lead to unwanted teeth movement and post-orthodontic treatment changes (8).

2.4 Types of Retainers

Retainers have been the standard retention method at the end of the orthodontic therapy to avoid relapse of the new occlusion and especially of the mandibular front teet (15). There are many suggested retention protocols after finishing the orthodontic treatment. Removable retainers like Begg wraparound retainer, Hawley retainer and wraparound clip retainers are the most common types of removable retainers (16). Currently removable vacuum formed clear retainers that fully covers the retained teeth are very popular retention methods (17). Hawley and wraparound retainers are the most commonly used retainers because of several advantages like easy to adjust, can be tolerated by the patients, and do not easily get stained as the clear vacuum formed (Essix) retainers and most importantly they can be considered to be more durable than the vacuum formed retainers. Some disadvantages can be related to Hawley and wraparound retainers such as being less esthetic than vacuum clear retainers having visible metal wire in front of the teeth and include multiple clasps used to attain the required retention. These retentive clasps are likely to create some gapes and/or to reopen the extraction spaces as reported specifically with the Hawley retainers. The other drawback of Hawley and wraparound retainer is their bulkiness which makes it less comfortable than the vacuum formed retainers. It has also been reported that they can potentially cause the patient to have excessive salivation and difficulty in speaking (16). However, clear vacuum formed retainers have several advantages such as being esthetically acceptable and they can efficiently retain the covered teeth in their position. On the other side, the occlusion remains disarticulated during the wearing time which in turn may not allow for a full occlusion settling between the upper and lower dental arches. Another reported drawback is that the vacuum formed material can easily get torn and this will subsequently decrease its efficiency - as in any removable retainer - is highly dependent on the patients compliance (17). Vacuum formed clear retainers have been reported to be more efficient in maintaining the stability of the lower incisors than Hawley retainers during the first 6 months after debonding (18).

Some cases require permanent retainers after finishing the orthodontic treatment. The most efficient way is to place a lingual bonded retainer. Fixed retainers are effective in long term retention and stability (16). Renkema et al. conducted a retrospective research and they found out that canine to canine fixed retainers are efficient in relapse prevention. They also revealed that retainer failure can compromise post treatment stability (19).

Different types of fixed retainers have been prescribed with different wire materials, properties and thicknesses (20). Various types of bonding materials have been described as well (21). Two various wire types of permanent lingual retainers bonded from cuspid to cuspid are usually applied in orthodontic practice: First type uses rigid, thick gauge (0.028-0.030 in) stainless-steel wires bonded to the cuspids only and the second type uses a thinner, flexible, spiral, multistrand wire that is bonded to the incisors and the cuspids. The second type is more commonly used (15) (22).

Fixed retainers bonded to the lingual surfaces of all anterior teeth are indicated in cases with lower incisor extraction, severe anterior teeth rotations pretreatment, diastema closure cases, and in cases with palatally impacted canine alignment (23).

In general, the fixed retainers bonded only to the canines can be used when sagittal or lateral movement of the anterior segment is achieved. Where as in cases where there is a risk of relapse for any individual tooth at the anterior region, its preferred to use fixed retainers bonded to each single tooth at the anterior region (3).

Rigid retainers maintain inter-canine dimension better but have less control on individual tooth rotations. The flexible wire retainers offer better control in preventing teeth rotations (22). It was found by Renkema et al. that with mandibular fixed lingual retainer bonded only on the cuspides, the index of irregularity of the mandibular incisors increased in the period 5 years after the orthodontic treatment (19).

The flexible multistrand retainer has additional several advantages. The presence of undercuts in the wire allow for the mechanical retention of the composite bonding material with the wire. The flexibility of the wire can reduce the stresses in the bonded composite that reduces the possible chances for failure and also the wire flexibility permit for slight physiological teeth movement that positively influence the periodontium making it more healthy (24).

Retainers made of fiber reinforced matrix have been introduced also as an alternative to wire retainers (25). Retainers made with fiber reinforced materials have a number of advantages like improved esthetics, serve as an alternative fixed retainer in patients with Nickel hypersensitivity and fabrication of fiber retainers often do not require plaster model. On the other hand, it has been reported that some clinicians find placing fiber reinforced retainers as a technique sensitive and more complex procedure than traditional wire fixed retainers (26).

Recently, CAD–CAM manufactured bonded retainers were introduced. Since this is a very modern technology limited researche about this technique is available. Different methods of manufacturing readymade bonded retainers utilizing CAD–CAM technology have been described. One method uses a handle of a CAD–CAM machine to bend a prefabricated copper–nickel–titanium wires to form lingual fixed readymade retainers (27). A second method uses CAD–CAM milling machine to carve nickel–titanium wires of 0.014×0.014 inch thickness into prefabricated lingual retainers (28).

2.5 Methods of Fixed Retainers Bonding

There are two common methods used for bonding fixed retainers. A direct method where the wire of the bonded retainer is fabricated on the cast and transferred to the mouth using a transfer key. The transfer key will assure placement of the wire in the right position. After positioning the retainer wire, composite can be applied directly on the teeth and cured intraorally following the common bonding steps. An indirect method can also be followed. In this method, dental cast will be used to fabricate a bigger transparent transfer key that will carry the retainer wire. The transfer key will also include spaces carved in it that will receive composite later while delivering the retainer clinically. Transfer key with the previous design will allow to position the composite pads intraorally with more accuracy in size and position. The clinical procedure of the indirect method will involve placing the wire and applying the composite on the transfer key extra orally then the key carrying the wire and the composite will be seated on the teeth intraorally. After seating light curing will be done throw the transparent transfer key.

The indirect method is more accurate and require less chair side time than the direct method (29). Both direct and indirect bonded retainers have similar failure rates. In terms of efficiency both bonding methods are effective in stabilizing inter canine width post treatment (30).

2.6 Advantages of Fixed Retainers

Fixed retainers have several benefits as they offer superior esthetics, patient cooperation is not required, and they are appropriate for lifetime retention thus making them the most popular system used (31). These retainers are very useful in situations where there is predicted instability and/or when dealing with patients with high expectations. Bonded retainers are less dependent on patient compliance and this is considered as one of their clear advantages (32).

2.7 Disadvantages of Fixed Retainers

Oral hygiene procedures often become more complicated with fixed retainers and this can be considered as a significant drawback of using them as they allow for the accumulation of plaque and calculus. Interdental cleaning aids and general cleaning measures are required to improve and provide adequate oral hygiene (33).

However, it has been reported in several publications, that there is no association between periodontal diseases and fixed retainers (34). Additionally, there is no proof that bonded retainers rise the prevalence of enamel white spot lesions (35). As shown in the available literature, bonded retainers might fail to maintain passivity and this can be due to many reasons such as improper selection or inadequate adaptation of the retainer wire to tooth surface, fatigue of the material caused by the forces of mastication, and/or the unwanted effect caused by failure of the bonding (36).

The most common disadvantage of the bonded retainer is its relatively high failure rate with the most common reason of failure to be retainer bonding failure at the interface between composite and enamel. This failure is especially common at the early retention stages and most frequently occurs at the canine region (32). It has been mentioned in the literature that the majority of bonded retainers' failure happens at the first three to six months of retention period and after the first year of retention phase the failure rate drops significantly (37). Failure of the retainers due to wire fracture can also occurs especially mesial to the maxillary canines due to occlusal trauma and it has been reported that this type of failure is the least common type (32). According to Dahl and Zachrisson, the most widespread negative effect of the fixed retainers is that the development of a small spaces (0.5-2 mm) in the first 6 months after debonding distally to the terminal unit of the retainer that can be unilaterally or bilaterally especially in extraction or bimaxillary proclination cases. According to the author these spaces stop from getting larger after the first 6 months of the retention period (35). Furthermore, failure of the boning or of the retainer wire can cause space opening in between the retained teeth (38). Occlusal contacts between the retainer composite or wire with the mandibular teeth result in faceting of the retainer wire and/or abrasion of the bonding composite that lead to retention failure (35).

It was suggested by Dahl and Zachrisson that in cases with tight occlusion a groove cut at the anterior teeth lingually can be drilled to place the retainer wire inside the groove so that the retainer wire will be kept away from the forces of occlusion (35). Some more downsides of the fixed retainers includes time-consuming bonding procedure which is technique sensitive (35) and rely on operator experience (35). There have been reports that over all failure of the bonded retainer is 53%, which is a high figure (39), and this failures of the bonded retainers may stay undetected by the patient leading to unwanted post orthodontic treatment changes and possible enamel demineralization lesions (3).

2.8 Fixed Retainers Repair

Becker and Goultschin reported that a failed retainer could be repaired without complete retainer removal by careful removal and replacement of a single failed bond. In cases of retainer wire section failure, that section can be removed and a new piece can be contoured and bonded into the place of the failed section (38).

If an inter-dental space developed between the upper or lower anterior teeth at the failed retainer section then a steel ligatures, elastics or finger pressure can be applied to close the space and a temporary labial retainer can be bonded at the diastema site to ensure temporary retention while the repair of the permanent lingual retainer is done (40).

2.9 Orthodontists' Preference

When choosing the appropriate retainer for each case, it is essential to consider clinical effectiveness as long as patient`s ability and compliance to use the retainer and to follow the retention protocol (16).

Most orthodontists favor both upper and lower dental arches to have fixed retainers at the end of the treatment except in extraction cases and/or in cases with expansion. In cases with expansion and/or extraction it is preferred to have a combination of fixed and removable retainers (41). According to Sfondrini et al., when determining the type of retention to use after completion of the treatment, several criteria should be taken in consideration such as type of malocclusion, patient compliance, oral hygiene, and patients' expectations (42).

Wong and Freer carried out a survey in Australia and New Zealand and they revealed that upper vacuum formed clear retainers and lower fixed canine to canine retainers were the most common retention protocol used among the surveyed orthodontists. Almost fifty percent of the orthodontists prefer to keep their retention for a particular period around two years. The study showed also that orthodontists participated in the survey have varied percentage among their cases where they used permanent bonded retention. The conclusion was that retention protocol were inconsistent and the type of retention decision was based largely on individual practitioner preferences. (43).

Another survey done in the Netherlands showed that high percentages of the orthodontists used the bonded retainers in both upper and lower arches and that among them 84% of them preferred lifetime retention when using fixed retainers (44).

2.10 Advantages of Fixed Retainers

Many studies reported a significant increase in post orthodontic treatment retention and stability of the mandibular labial segment in patients with lower bonded retainers in comparison to patients with lower vacuum removable clear retainers.

In 2017 a randomized controlled clinical trial showed that bonded retainers in the mandibular arch maintained the alignment of the lower anterior teeth - 12 months after finishing the orthodontic treatment - significantly better than the vacuum formed clear retainers. Nevertheless, the study showed that there is higher rate of failure in the bonded retainer group in comparison to the removable clear retainer group (32).

A later study that involved four years follow up of a randomized controlled clinical trial testing the stability of the lower anterior teeth with bonded retainers versus vacuum formed clear retainers showed that Little's irregularity index at the end of the study was significantly lower - by approximately 1.6mm - in the bonded retainers group in comparison to the other group and they concluded that fixed retention is more efficient in maintaining the alignment of mandibular anterior segment (45).

The results of the previous studies indicate that the benefit of having fixed retainers is more essential and evident on long-term retention periods. It also reveals that by having fixed retention, practitioners can potentially reduce post-orthodontic changes caused by instability in teeth positioning at the end of the orthodontic treatment, changes caused by growth and/or maturation and patients not compliant in wearing their removable retainers. Based on the previous points it can be expected that in the removable retention group further changes might occur on the long term making the difference between the two groups even bigger (32) (45).

The discussion above emphasizes the importance of long-term fixed retention to ensure stability on the long run. It also reveals that there is a higher failure frequency associated with fixed retainers. Based on that, active measures should be taken to minimize the failure rate by conducting further studies to find out which materials used in fixed retainers have potentially higher survival rate.

2.11 Dental Composite

Composite resins containing bisphenol A diglycidylmethacrylate (bis-GMA) are utilized in dental practice to bond bonded retainers and orthodontic brackets (12). Adhesion between dental enamel and composite resins with an acceptable clinical intraoral survival time was not possible until enamel acid etching protocol was introduced and established in 1955 (46). Several in vitro ultrastructural studies on acid etching effect on enamel surface were conducted to establish and develop the initial phosphoric acid-etching technique (47). Based on results from these laboratory studies, the resulted optimum clinical bonding procedure is now commonly accepted. The main aim of dental bonding protocol is to form microscopic troughs in the enamel sheaths and cores structures in order to facilitate mechanical interlocking between resin tags and enamel. In general, dental composite bonding requires adequate wetting of the enamel surface by the liquid composite. This requirement is a critical step to allow dental adhesion between etched enamel surface and resin composite. The previous criteria shape the foundation of the extensively accepted protocol of enamel adhesion mechanism (22).

Adhesive composites are commonly used in dentistry, and their clinical performance and durability are highly depending on their mechanical properties. Mechanical properties requirements for adhesives used to bond fixed orthodontic retainers are different for adhesives applied somewhere else in dentistry like adhesives used to bond brackets (48).

Furthermore, a larger surface area of the composite resin used in lingual retainer remains subjected to the oral environment than in other composites used in dentistry like prosthetic luting composites or of bracket adhesives. Hence, dental composite material wear resistance and hardness are among the essential mechanical properties for the durability of bonded lingual retainers in intra oral circumstances (49).

Additionally, composites used with permanent retainers are more susceptible to aging processes as they stay in the oral environment for lengthier period of time than adhesive composites used for bracket bonding for example (50).

It is well understood that dental resin composites are exposed to intraoral aging from subjecting to mechanical and thermal stresses (51). Even though numerous lab studies aimed particularly on chemical, thermal, or mechanical loads associated effect on the dental composite resins, there is in general limited data on the impacts of intraoral environment long-term effect on composites properties (52). Oral effects on the long run might alter composite resins structural integrity and affect an essential elements of material properties like mechanical performance and strength (53).

Different clinicians used different materials to bond lingual fixed retainers. Radlanski et al. used microfilled composite (Heliosit®) and microfilled hybrid composite (Tetric® Flow) (54). Baysal and Uysal used resin-modified glass ionomer cement (RMGIC) (Fuji Ortho-LC) and conventional orthodontic composite (Transbond-LR) (55). Veli et al. used self-adhering flowable composite (Vertise™ Flow) and conventional orthodontic composite (Transbond-

LR) (56). Aldrees et. al. used FlowTain™, a flowable lightcured resin, Light Cure Retainer™, a highly filled light-cured resin, and Transbond™ LR, a highly filled light-cured resin (57). Scribante et al. used flowable nanocomposite Filtek Supreme XTE (FL) and highly filled orthodontic resin Transbond XT (XT) (58). Sifakakis et al. used Transbond XT, Transbond LR and an experimental BPA-free (conventional orthodontic composite adhesive), as well as IPS Empress Direct (IPSED) (nanohybrid restorative), ZNano (nanoparticle restorative) and Accolade (microhybrid flowable restorative) (59). Pandis et al. used Cure 2-part liquid adhesive (Reliance Orthodontic Products, Itasca, Ill) and Excel 2-part paste (Reliance Orthodontic Products) as chemically cured composite group and photo polymerized light-cured liquid (Assure; Reliance Orthodontic Products) and paste (Flow-Tain; Reliance Orthodontic Products) as a light-cured adhesive composite (21) (60).

2.12 Survival Rates of Various Types of Fixed Retainer Bonding Materials

Many studies compared mechanical properties of different bonding materials types used in fixed retainers. Radlanski et al. compared the vertical shear bond strength of microfilled composite (Heliosit®) to microfilled hybrid composite (Tetric® Flow). This study concluded that there was no difference between these two composites as significance level was not reached. However, improved results were noted with Tetric® Flow bonds over Heliosit® Orthodontic bonds (54).

Another study conducted by Baysal and Uysal compared resin-modified glass ionomer cement (RMGIC) (Fuji Ortho-LC) to conventional orthodontic composite (Transbond-LR). They tested shear bond strength (SBS), fracture mode, and wire pull out (WPO) resistance of the two materials. They reported that there was no significant difference among the two materials in fracture mode. But, the resin-modified glass ionomer cement resulted in a significant decrease in shear bond strength and wire pull out (55).

Veli et al. aimed to evaluate the shear bond strength (SBS) and fracture mode of a self-adhering flowable composite (Vertise™ Flow) and to compare it to conventional orthodontic composite

(Transbond-LR). They revealed that Vertise™ Flow, which is a resin-based self-adhering, light-cured flowable composite, resulted in a significant decrease in shear bond strength than conventional orthodontic composite (Transbond-LR) (56).

Aldrees et al. aimed to test initial bond strength in vitro of three lingual fixed retainer composites (FlowTain™ a flowable lightcured resin, Light Cure Retainer™ a highly filled light-cured resin and Transbond™ LR a highly filled light-cured resin). Bond failure evaluations showed that Transbond™ LR had the highest bonding strength whileadhesive Light Cure Retainer™ had the lowest (57).

A laboratory and clinical study done by Scribante et. al. conducted to check the reliability of the flowable nanocomposite Filtek Supreme XTE (FL) compared to highly filled orthodontic resin Transbond XT (XT) when used as bonding composite for orthodontic retainers. Filtek Supreme XTE (FL) showed significantly higher failure rates in both mandible and maxilla. Furthermore, Filtek Supreme XTE (FL) showed a significantly lower survival rate after 6 monthes or retainrs bonding. They recommended Transbond XT (XT) to be used as a preferred bonding composite in fixed retainers (58).

Sifakakis et. al. tested the mechanical properties of Transbond XT, Transbond LR and an experimental BPA-free (conventional orthodontic composite adhesive), as well as IPS Empress Direct (IPSED) (nanohybrid restorative), ZNano (nanoparticle restorative) and Accolade (microhybrid flowable restorative). They subjected these materials to Martens hardness (HM), indentation modulus, the ratio of elastic to total work, commonly known as elastic index and Vickers hardness (HV) tests. Their results showed that in Martens hardness test there was significant statistical differences between all materials used in the study and Transbond LR had the highest value. Indentation modulus test came out with significant statistical difference between the composites and only ZNano and IPS-ED showed no significant differences while Transbond LR presented the highest value. Higher Vickers hardness test results obtained in Transbond LR and ZNano groups. The highest elastic index score was achieved by ZNano. In summery the materials included in this study revealed significant differences in their mechanical properties, and it can be anticipated that their clinical performance is going to be different (59).

A comparison between fixed retainers bonded using chemically cured or light-cured adhesive was done by Pandis et al. Two groups entered this study. Cure 2-part liquid adhesive (Reliance Orthodontic Products, Itasca, Ill, USA) and Excel 2-part paste (Reliance Orthodontic Products) were used in the chemically cured composite group. The second group used photo polymerized light-cured liquid (Assure; Reliance Orthodontic Products) and paste (Flow-Tain; Reliance Orthodontic Products) as a light-cured adhesive composite. This study concluded that there is no statistical evidence that survival rate of fixed lingual retainers in the mandible is different between light-cured and chemically cured composites (21). Anotherstudy conducted by Gugger et al. used the same materials and they stated that there is no evidence that failure rate is different between chemical or light-cured composite (60).

2.13 Wear Test

Attritional wear resistance of the fixed orthodontic retainer bonding materials restricts the service time of the device . Hence, the attritional wear rate of composite resins used to bond the lingual fixed retainers should be more or less similar to the attritional enamel wear rate (61). Abrasive wear and attritional wear have been recognized as the two major processes of dental materials wear (62).

Abrasive wear takes place because hard particles squeezed and moved along hard surfaces. It t can be categorized into two-body abrasion and three body abrasion. The main difference between two-body abrasion and three body abrasion is that in three-body abrasion the particles are loose in the slurry in between the two solid surfaces whereas in two-body abrasion these abrasive particles are fixed on one or both surfaces. Attritional wear is defined as two body abrasion wear while teeth or restorations are in occlusal contact (63).

ln 2001 an attempt was made to standardize two- and three-body wear testing with a technical ISO specification (64). Laboratory determination of wear rates using chewing simulators seems to be an important aspect in laboratory evaluation of composite resin materials (65).

Dental composites wear was explained by Sarkar as a process that includes a series of events during which materials' wear begins usually intraorally with water absorption (66). Water absorption leads to hydrolytic degradation of the silane coupling interface found between composite fillers and resin matrix. Internal diffusion of water through the organic matrix resin, material pores, defect and fillers boundaries gradually dissolve filler particles. This process slowly compromises the reinforcement effect of the dental composite inorganic fillers. The consequence of the latter is the formation of a layer of corroded subsurface which is weaker, softer and has increased porosity that can be subjected easily to wear and surface changes (66).

Many authors tested and compared surface material wear of various dental products . Some studies included materials that are used in bonding fixed orthodontic lingual retainers. According to Nayyer et al. , Microhybrid resin composite (Filtek Z350) showed higher material hardness value compared flowable composite. This may be because Filtek Z350 composite has increased filler content and greater filler particles surface area that have possibility to enhance the interfacial bonding between resin and fillers. The reduction in surface hardness associated with the flowable composite in their study can be related to reduced filler loading compared to Filtek Z350 (67).

Viana et al. compared in their study material surface loss of Microhybrid resin composite (Filtek Z350) Resin Modified Glass Ionomer (Fuji II LC) after erosive and abrasive challenges. The Resin Modified Glass Ionomer showed increased material surface loss values after erosive test than Filtek Z350 composite. The reason behind their findings can be due to the dissolution of the external lattice of silicate hydrogel in the glass particles structures since Glass Ionomers composition tend to show greater solubility in aqueous intermedia (68).

De Paula et al. tested nanofilled composite 3M/ESPE Filtek Z350 and 3M/ESPE Ketac Resin Modified Glass Ionomer regarding thair surface roughness resistance and morphology changes to cumulative biofilm plus tooth-brushing Three-body Abrasion Test challenges. The nanofilled composite Filtek Z350 demonstrated a greater resistance to surface roughness after abrasion testing. They stated that Filtek Z350 composite content of hydrophobic monomers like TPH Spectrum matrices and Bis-EMA - ethoxylated bisphenol-A dimethacrylate, which is an ethoxylated edition of the Bis-GMA, most likely provided their more resistance to surface changes behavior. On the other hand, the nanofilled resin-modified glass ionomer, 3M/ESPE Ketac, significantly demonstrated increased roughness rate in comparison with the 3M/ESPE Filtek Z350 composite. A fair description for this severe degradation can be due to the precense of 2-hydroxyethyl methacrylate (HEMA), BisGMA and TEGDMA in the material matrix. It was reported that in aquatic medium, microphase separation of Bis-GMA/HEMA happens. The hydrophobic camphoroquinone leaves hydrophobic Bis-GMA phase while tertiary amine hydrophilic end leaves in the hydrophilic HEMA phase. The previous process reduces the probability of Bis-GMA/HEMA contacting each other; hence, in in the Ketac matrix, a lesser level of conversion setting reaction could happen. They advised that clinical finishing and polishing of the surface layer may have a tendency of making the nanofilled RMGICs surface more resistant surface changes and roughness, and consequently, more stability (69).

Bansal et al. compared surface wear of resin-modified glass-ionomer (RMGI) restorative material to a flowable resin composite (Filtek Supreme Ultra). They concluded that flowable resin composite (Filtek Supreme Ultra) surface wear was significantly less than resin-modified glass-ionomer (RMGI) (70).

A study conducted by Correr et al. aiming to evaluate resin-based materials wear after corrosive and abrasive tests. In this study they found that RMGI demonstrated the lowest resistance to wear among other conventional composites materials tested in the study. They related the relatively increased RMGI wear to the properties of the material itself. The main properties of RMGI are lower mechanical properties and increased roughness in comparison to conventional composites. They related the increased wear values of the RMGI to the formation HEMA particles crosslinking between polyacid chains of the material. This HEMA crosslinking requires specific gaps between the two polyacid chains joined together preventing them from being in closer contact. At the HEMA crosslinking regions polyacid chains carboxylate groups are situated away from reach other to form crosslinkage throw calcium ions. Calcium crosslinking betewwn polyacid chains could be possible if the material doesn't have the organic crosslink (HEMA). Therefore, carbon double bond interaction of the HEMA crosslinking could cause destabilizing and separation of the polyacid chains adequately to reduce the ionic interactions between the chains as would normally - if present - provide the material with greater stiffness, hardness and surface indentation and wear resistance. Another cause of increased wear of RMGI in comparison to conventional composite can be due to the fact that RMGI has increased porosities. Additionally, the larger size of the filler particles, the reduced filler content, and the inferior crosslinking between RMGI fillers and resin matrix are another contributing reasons for the increased surface wear of the Resin Modified Glass Ionomer (71).

When Sifakakis et al. compared Martens hardness (HM), indentation modulus and Vickers hardness (HV) properties of Transbond XT to other dental orthodontic adhesives as well as flowable composite and conventional composite. Transbond XT was significantly higher in Martens hardness (HM), indentation modulus and Vickers hardness (HV) values than the flowable composite. According to their study Transbond XT as well was significantly higher in Martens hardness (HM), indentation modulus and Vickers hardness (HV) values than the IPS Empress Direct (conventional restorative composite). IPS Empress Direct is a nanohybrid direct dentin conventional restorative composite composed of UEDMA, TCDDMA and BisGMA as resin matrix and Ba-Al-fluorosilicate (0.7 μm), ytterbium trifluoride (100 nm) and prepolymers (1–10 μm) as a filler particles with 80% by weight of total fillers loading (59).

The previous two different tests of the same property were conducted for these reasons: Vickers hardness tend to have accuracy issues with the optical system resolution limitations, operator’s influence by his perception and material rebound around the area of indentation testing. On the other hand, Martens hardness is obtained by a completely automatic prosses that has a possibility to solve the previous issues affecting the accuracy of the hardness test. Nevertheless, in the literature they found no data for previous Martens hardness test in dental researches and that’s why Vickers hardness was selected to have a comparison with earlier experiments. They concluded in their study that Transbond XT was the most ductile material among the materials tested (59).

3. AIM

The purpose of this study was to evaluate the three-body abrasion wear of four composite resins - with different resin type and filler content - used to bond the fixed orthodontic wire retainer after chewing simulator loading.

4. HYPOTHESIS

Hypothesis: there are significant differences in the wear resistance among the different composites used in orthodontic fixed retainers.

Null hypothesis: there are no significant differences in the wear resistance among different composites used in orthodontic fixed retainers.

5. MATERIALS AND METHODS

This in vitro study was conducted using eighty acrylic molds made of cold self-setting dental acrylic material. Each mold included maxillary right and left hard thermosetting plastic central incisors (frasaco, Tettnang, Germany) to resemble the natural teeth. Molds were divided into four equal groups according to the type of the composite resin materials with twenty molds in each group.

Twist flex wire (size 0.0195”) (16 mm in length) used to fabricate the permanent retainers used in this study. Permanent retainers were bonded to the upper right and left central incisors using one of the assigned composite resin materials in each group.

The composite resin materials used in this study are shown in Table 1.

Table 1. The four different bonding materials used in the test.

Material Manufacturer: 3M Espe	Type	fillers wt %	Composition
Filtek Z350	Conventional nanofilled	**78.5**	Bis-EMA, Bis-GMA, TEGDMA, PEGDMA, UDMA Zirconia, silica
Transbond XT	Orthodontic adhesive	**77**	Bis-EMA, Bis-GMA, Silica
Filtek Flowable	Flowable nanofilled	**50**	Bis-GMA, TEGDMA, UDMA Zirconia, silica
Ketac Nano	RMGI	**69**	Bis-GMA, TEGDMA, PEGDMA, HEMA, Zirconia, silica Glass powder, Acrylic polymers, itaconic acids

Samples were prepared and bonded by the same investigator in order to ensure consistency in all steps required for molds preparation, bonding of the permanent retainers, and testing the wear strength. Bonding process was performed for all permanent retainers using the same light curing polymerization protocol (Satelec Mini LED Curing Light, Mérignac, France) (1,250 mW/cm2) 440 - 460 nm for 40 seconds with the light curing device tip around 1 mm away from the composite.

In order to imitate physiological tooth mobility, roots of the plastic teeth were coated with an artificial periodontal membrane made from polyether impression material (Impregnum Soft Light Body, 3M ESPE, Seefeld, Germany) before molding (72). A dual axis chewing simulator machine (Willytec, Munich, Germany) was used to perform the wear test (Figure 2). Molds were mounted in the chewing simulator machine by the same investigator. A plastic container was placed around each mold in order to keep the abrasive media around the test samples (Figure 1). Molds were coded from 1 to 80 by a second investigator so that the main investigator who performed the wear resistance test was blinded.

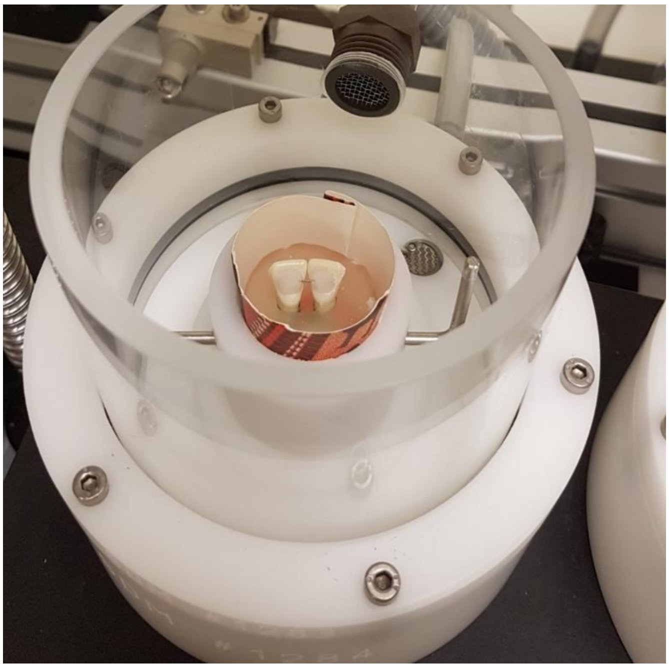

Figure 1. Right and left hard thermosetting plastic central incisors (frasaco, Tettnang, Germany) are mounted in the acrylic mold using cold self-setting dental acrylic material. The retainer wire and its bonding material are bonded to the plastic teeth.

To perform the three-body abrasion test using the chewing simulator machine, the abrasive media was prepared by grinding 30 g of millet-seed and 120 g white rice for 60 seconds then it was mixed with 275 ml of distilled water and placed in a the containers around the plastic teeth sample (73). Steatite ceramic balls (Hoechst Ceram Tec, Wunsiedel, Germany) with a diameter of 6 mm were used as antagonistic specimen to substitute enamel abraders (74) (75). The ceramic balls were positioned to be approaching the maxillary right central incisor plastic tooth. A stopper was placed in order to prevent the ceramic ball from touching the composite by holding the ceramic 1 mm away from the composite resampling the natural overjet and overbite. This step helps in resembling the clinical situation where lower teeth do not contact the composite of the maxillary retainer while the wear of the fixed retainer composite is mostly done by the food particles.

The parameters of the wear test are listed in Table 2.

Table 2. Dual axis chewing simulator machine parameters of the wear test.

Test parameters of the chewing simulator	
Vertical movement	6mm
Rising speed	55mm/s
Descending speed	30mm/s
Kinetic energy	2250×10−6
Weight per sample	5 kg
Cycle frequency	1.3 Hz

The effective weight of each antagonistic specimen is 5 kg, which corresponds to a loading force of 49 N (76). To simulate clinical intraoral performance of the bonded retainer composites, a total of 200,000 loading cycles were performed under the chewing simulator.

Figure 2. Eight samples are mounted and subjected to chewing simulator test using dual axis CS-4 chewing simulator (SD Mechatronik, Munich, Germany).

Figure 3. Computer-aided 3D scanner machine - Ceramill® map 200+ (Amanngirrbach, Koblach, Austria).

In order to measure composite material wear changes before and after the chewing test, computer-aided extraoral 3D scanner Ceramill® map 200+ (Amanngirrbach, Koblach, Austria) (Figure 3) was used to scan all models at three different time points, T1: before bonding permanent retainers, T2: after bonding permanent retainers and before chewing test, and T3: after chewing test. Scanning data was saved in STL format.

The scanned 3D files were analyzed by an IT professional using Blender.app PC software, 2.81a version (Blender Foundation, Amsterdam, The Netherlands). Since the ceramic ball of the chewing simulator was approaching the left central incisor, only the left central incisor 3D models were analyzed.

The volume of the composite resin material in each group was calculated by superimposing T1 and T2 scanning data (Figure 4). The same software was used to segment and subtract the superimposed tooth structures in T1 and T2 scanning data from the composite resin material in T2 scanning data. This step was performed to calculate the volume of the composite resin used to bond the permanent retainer in mm^3.

The same steps were performed to superimpose T1 and T3 scanning data in order to calculate any changes in the volume of the composite resin before and after performing the wear test using the chewing simulator machine. By performing this step, the before and after volume of all composites subjected to chewing test were obtained.

Bonding material volume loss of each sample was assessed by subtracting the pre-chewing test composite volume (T2) from the post-chewing test composite volume (T3) of the same sample.

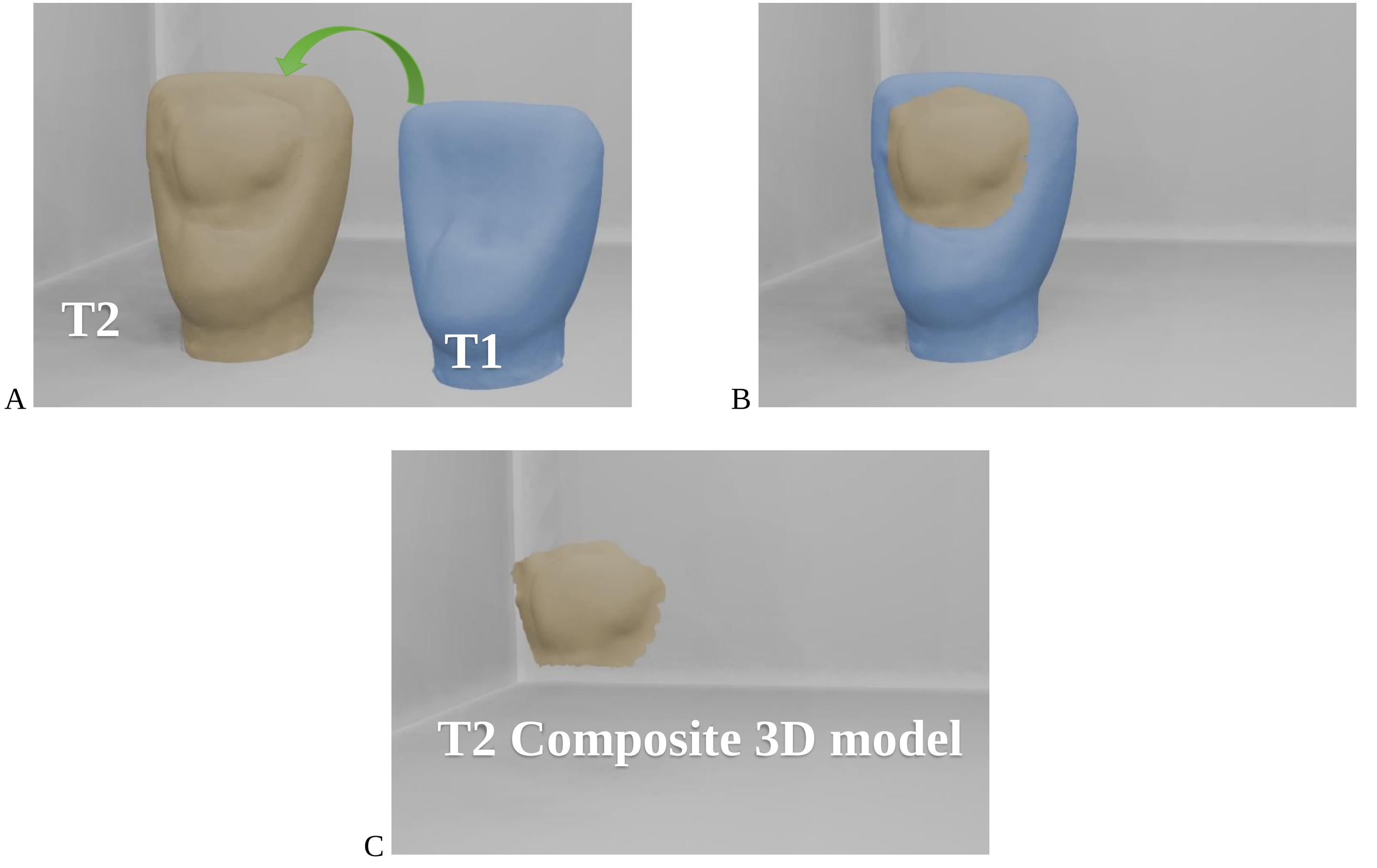

Figure 4. Demonstration of sample 3D manipulation to crop the tooth structure leaving the composite 3D model alone to compute composite volume.
(A) Blender.app automated placement of T1 scan of the same sample on top of T2 scan.
(B) after placement of the T1 3D scan on top of T2 scan.
(C) After cropping all the volume of T1 3D model and all the structures that it covers leaving T2 composite 3D volume only.
After C Blender.app software will calculate the volume of the composite 3D model.
Note: To compute composite 3D exact same steps will be repeated with T3 scan instead of T2 scan

5.1 Statistical Analysis

Data was entered in computer using IBM-SPSS for Windows, version 23.0 (SPSS Inc., Chicago, IL, USA). Measure of composite volume pre and post chewing test as well as composite volume loss were performed as descriptive statistics for continuous data. Shapiro-Wilk was used to test the normality of all continuous variables. Levene's test was performed on the volume loss variances of the four groups in order to check if there is statistically significant difference between the variances of the four groups in order to verify that the variances of the four groups are homogeneous.

ANOVA test was used to test if there is statistically difference in composite volume means between the four groups. ANOVA was done to check volume change means of the four groups. The post-hoc Tukey test (HSD) was implied for multiple pair-wise comparisons of volume loss means between the four composites groups.

Test-retest reliability was used to measure data correlation coefficient of randomly chosen ten samples at two different time points obtained by the same IT professional operating the 3D software. This test was done by conducting volume test on same ten samples two times with an interval of one week. This test was computed using Pearson product-moment correlation coefficient (Pearson's r correlation). A P-value ≤ 0.05 was considered significant in all statistical analyses.

Power calculation for One-way independent ANOVA was performed to check whether we obtained acceptable power with the used sample size. Cohen`s suggested effect size was followed in power calculation. Since Cohen suggests that effect size (f values) of 0.1, 0.25 and 0.4 represent small, medium and large effect sizes respectively, large effect size of 0.4 was used in this study. Power calculation showed that the power of the study was 84.5% (Table 3).

Table 3. Power calculation for One-way independent ANOVA

Statistical Test	**Number of Groups**	**Sample Size**	**Power**	**Effect size**	**Significance Level**
ANOVA	4	20	0.8454	0.4	0.05

The justification of choosing 0.4 effect size is that effect size calculation based on the following formula was (0.84).

$$f = \sqrt{\frac{\sum_{i=1}^{k} p_i * (\mu_i - \mu)^2}{\sigma^2}}$$

Since 0.84 is considered a very large effect size, it will be acceptable to use Cohen`s large effect size (0.4) without over estimating the effect size value.

6. RESULTS

Descriptive statistics for all collected data were calculated for all different types of composite resin materials and presented in (Table 4). Shapiro-Wilk test showed that all the measurements were normally distributed as p-values were higher than 0.05 for all measurements (Table 5). Comparison of the mean difference before and after the wear test in each group showed statistically significant decreases indicating significant volume change in all composite resin materials (Table 6). The mean difference in the volume loss in all groups can be arranged in the following ascending order: Filtek Z350, Trans-bond XT, Filtek Supreme Ultra, Ketac Nano. Filtek-Z350 showed the lowest volume loss measures and Ketac Nano showed the highest volume loss values (Table 6). Box plots chart showing the means and 95% confidence interval of the four-materials volume loss is presented in (Figure 5).

ANOVA test on volume change means of the four groups disclosed that the p-value is less than 0.001 indicating that there is statistically significant difference in composite volume change means between the four groups (Table 7).

Filtek Z350 showed statistically significant decreases with all other composite materials using Post Hoc test. Filtek Supreme Ultra showed statistically significant increases with Filtek Z350 and Trans-bond XT, and statistically significant decreases with Ketac-Nano. Trans-bond XT showed statistically significant increases with Filtek Z350 and statistically significant decreases with each of Filtek Supreme Ultra and Ketac-Nano. Ketac-Nano showed statistically significant increases with all other composite materials using the same test (Table 8).

Test-retest reliability test computed using Pearson product-moment correlation coefficient obtained 0.998 as Pearson's r correlation value.

Table 4. Descriptive statistics of Filtek Z350, Filtek, Transbond XT and Ketac Nano Supreme Ultra groups before and after the test along with composite volume change (in mm3).

	Filtek Z350			**Filtek Supreme Ultra**			**Transbond XT**			**Ketac Nano**		
Parameters	pre	post	volume change	pre	post	volume change	pre	post	volume change	pre	post	volume change
No.	20	20	20	20	20	20	20	20	20	20	20	20
Mean	5.066	5.046	0.020	5.130	5.042	0.088	5.332	5.283	0.049	5.122	5.019	0.102
SD	0.344	0.346	0.009	0.490	0.490	0.014	0.392	0.391	0.011	0.482	0.484	0.014
minimum	4.426	4.391	0.008	4.380	4.296	0.063	4.692	4.644	0.031	4.481	4.359	0.078
maximum	5.904	5.880	0.039	5.904	5.822	0.112	5.851	5.812	0.072	5.977	5.875	0.127
95% CI	4.905 - 5.227	4.884 - 5.207	0.016 - 0.024	4.900 - 5.359	4.813 -5.271	0.081 -0.094	5.149 - 5.516	5.100 - 5.466	0.044 - 0.541	4.896 – 5.347	4.793 -5.246	0.096 – 0.109

Table 5. Shapiro-Wilk test of normality of all measurements shows that all the measurements were normally distributed.

Type of measurements	Shapiro-Wilk test of normality		
	Statistic	Df	P-value
Pre Filtek Z350	0.980	20	0.940
Post Filtek Z350	0.982	20	0.960
volume change Filtek Z350	0.930	20	0.158
Pre Filtek-Supreme Ultra	0.917	20	0.085
Post Filtek Supreme Ultra	0.914	20	0.077
volume change Filtek Supreme Ultra	0.968	20	0.703
Pre-Trans-bond XT	0.904	20	0.050
Post Trans bond XT	0.907	20	0.056
volume change Trans bond XT	0.966	20	0.666
Pre Ketac-Nano	0.927	20	0.134
Post Ketac Nano	0.927	20	0.137
volume change Ketac Nano	0.996	20	0.537

* Significant at P <0.05

Table 6. Pairwise volume loss comparison per the four materials

	Mean difference	p-value
Pre Filtek Z350 - Post Filtek Z350	0.020 (0.009)	< 0.001
Pre-Filtek Supreme Ultra - Post Filtek Supreme Ultra	0.088 (0.014)	< 0.001
Pre-Trans-bond XT - Post Trans-bond XT	0.049 (0.017)	< 0.001
Pre Ketac-Nano - Post Ketac Nano	0.102 (0.014)	< 0.001

* Significant at P <0.001

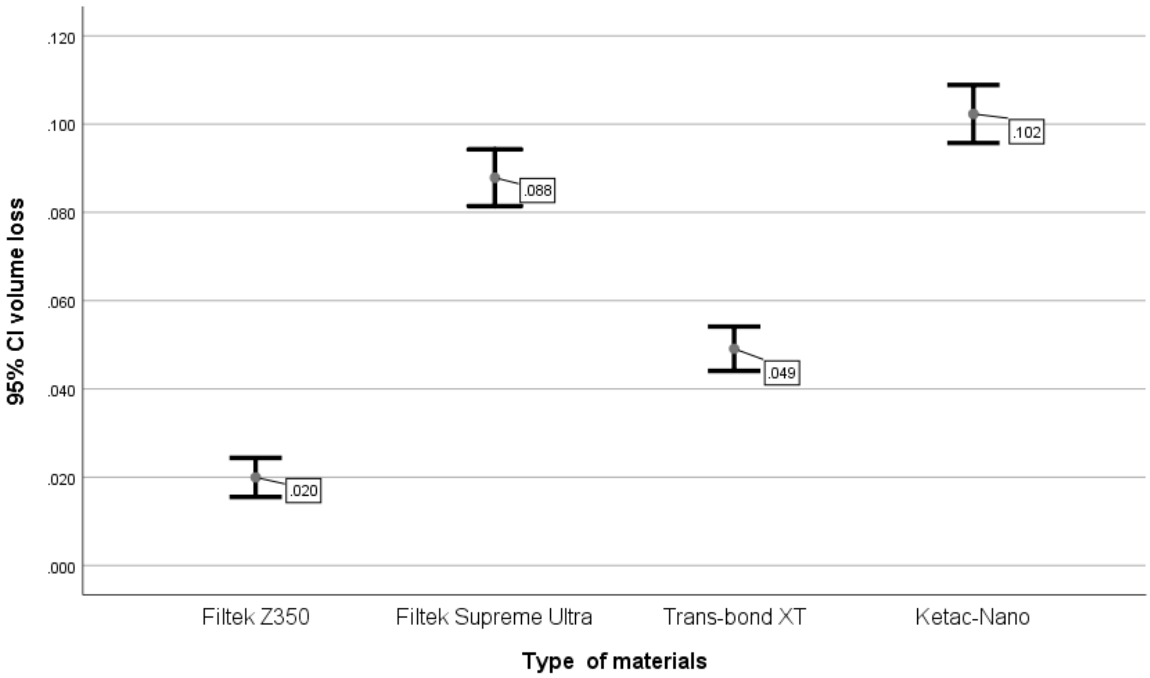

Figure 5. 95% CI of the difference of pre-post by material - Univariate Analysis (ANOVA).

Table 7. Comparison of the means of volume change between materials (ANOVA).

				95% CI	
				Lower	Upper
		Mean	SD	Bound	Bound
Filtek Z350	20	0.020	0.009	0.016	0.024
Filtek Supreme Ultra	20	0.088	0.014	0.081	0.094
Trans-bond XT	20	0.049	0.011	0.044	0.054
Ketac-Nano	20	0.102	0.014	0.957	0.189

p-value of the comparison is < 0.001

Table 8. Pairwise t-test by using Post Hoc test showed significance differences in the volume change in all groups.

Pairwise test	Materials	Mean difference (SD)		P-value
Filtek Z350	Filtek Supreme Ultra	-0.068	0.003845	< 0.001
	Trans-bond XT	-0.029	0.003845	< 0.001
	Ketac-Nano	-0.082	0.003845	< 0.001
Filtek Supreme Ultra	Filtek Z350	0.068	0.003845	< 0.001
	Trans-bond XT	0.039	0.003845	< 0.001
	Ketac-Nano	-0.014	0.003845	< 0.001
Trans-bond XT	Filtek Z350	0.029	0.003845	< 0.001
	Filtek Supreme Ultra	-0.039	0.003845	< 0.001
	Ketac-Nano	-0.053	0.003845	< 0.001
Ketac-Nano	Filtek Z350	0.082	0.003845	< 0.001
	Filtek Supreme Ultra	0.014	0.003845	< 0.001
	Trans-bond XT	0.053	0.003845	< 0.001

7. DISCUSSION

Maintaining a stable treatment outcome is one of the most difficult challenges in orthodontic treatment. Changes that occur in arch length, width, teeth alignment are common post-orthodontic treatment changes (4). Therefore, orthodontic retention is routinely planned for almost all treated malocclusions (5). Fixed retainers are indicated for long-term retention of the anterior teeth, especially for patients who had crowding, rotations, or midline diastema. With the introduction of the acid etched bonding methods in the dental field in 1973, Knierim and others introduced the use of lower cuspid to cuspid lingual fixed retainers (6). Multiple retention protocols including fixed and/or removable retainers have been reported in the literature. Among removable retainers, Begg wraparound and Hawley retainer are the most commonly used (16). At present, vacuum formed removable clear retainers are considered as popular retention methods as they are esthetically more acceptable (17).

Numerous literature reported a significant increase in post-orthodontic stability of the mandibular labial segment in patients with lower permanent retainers in comparison to patients with lower removable vacuum formed clear retainers. A randomized controlled clinical trial conducted by Forde et al. demonstrated that 12 months after finishing the orthodontic treatment, permanent mandibular retainers significantly maintained the alignment of the lower anterior teeth better than the vacuum formed removable clear retainers (32). A four years follow up randomized controlled clinical trial showed significantly lower Little's irregularity index value in the patient's group who had permanent retainers in comparison to the vacuum formed removable clear retainers group. It has been concluded that permanent retention is more efficient in maintaining the alignment of the mandibular anterior segment than the removable retention (45). Based on the previous reports it can be estimated that further changes might occur on the long-term with the removable retention group making a remarkable difference in the efficiency of both retention methods (32) (45). This highlights the significance of long-term permanent retention to enhance long term stability.

Forde et al. reported a significant failure rate associated with permanent retainer than removable clear retainer (32). With this been said, it can be concluded that more efforts should be taken to minimize the failure rate of the permanent retainers and that further studies should be conducted to confirm what permanent retainers materials would have a higher survival rate. Since dental composites are the material of choice that is used for bonding the permanent retainers, a thorough investigation of their mechanical properties is necessary to predict their durability and clinical performance. Moreover, a large surface area of the composite materials used to bond the fixed retainer remains exposed to the oral environment. Thus, retainer's composite wear resistance and hardness are among the important mechanical properties for the durability of permanent lingual retainers in the clinical environment (49). Since they remain in the oral cavity for a longer period of time, composites used to bond fixed retainers are more subjected to aging processes (50). Long-term intraoral environment effect on fixed retainers composite could change composite material properties like mechanical performance, strength, and wear resistance (53). Although several studies targeted particularly on thermal, chemical, or mechanical loads effect on the properties of the dental composite materials, there is limited data on the effects of long-term clinical service on retainers bonding composites properties (52).

Permanent retainer wear resistance limits the service duration of the fixed orthodontic retainers (61). Laboratory retainer composites wear test studies using chewing simulators appear to be a valid method in laboratory wear resistance evaluation of retainers composite materials (65).

Abrasive wear and attritional wear have been recognized as the two major processes of dental materials wear (62). Since retainer composite is not subjected to direct contact with opposing teeth, most of retainer composite wear is going to happen because of the abrasion caused by chewing food particles. That is why in our study we tried to simulate the intraoral food particles effect by conducting three body abrasion test. In three body abrasion test abrasion particles are loose in the slurry in between the two solid surfaces (63). To simulate food particles three-body wear testing ISO specification was followed (64) in the preparation abrasion material of the three body abrasion test (73).

Our study's aim was to compare the wear resistance of Filtek Z350, Trans-bond XT, Filtek Supreme Ultra, and Ketac Nano. The aim was driven from the fact that there is no study at the present comparing the wear resistance of these four materials. The choice of the previous materials was based on data found in the previous literature that used the mentioned materials as fixed retainer bonding materials.

This study was performed to investigate changes in material volume of the different composite resin materials before and after the wear test using a chewing simulator machine. The samples ware scanned using the 3D scanner and digitally analyzed to evaluate volume changes.

Comparison between the four groups showed statistically significant decreases in the mean difference before and after the wear test using the chewing simulator machine. These findings indicate that there was significant volume loss in all composite resin materials.

According to our study material resistance to three body abrasion test can be arranged in the following ascending order Filtek Z350, Trans-bond XT, Filtek Supreme Ultra, Ketac Nano with a highest abrasion resistance in Filtek-Z350 and a lowest abrasion resistance in Ketac Nano.

A reasonable explanation behind the differences found in the wear resistance between the four different composite resin materials can be related to the variations in fillers loading among these materials (59). Materials with high fillers content like Filtek Z350 that contains the highest fillers percentage among the other tested materials tend to have the highest wear resistance. On the other hand, Ketac Nano had the lowest fillers content causing it to be the least material to resist wear.

One-way ANOVA test revealed that there is a statistically significant difference between the four groups volume change means (p-value < 0.001) (Table 7). Therefor, the null hypothesis is rejected.

Pairwise Post Hoc test t-test showed that there is significant difference among each two pairs of the four materials. Filtek Z350 showed statistically significant decreases with all other composite materials using Post Hoc test. Filtek Supreme Ultra showed statistically significant increases with Filtek Z350 and Trans-bond XT, and statistically significant decreases with Ketac-Nano. Trans-bond XT showed statistically significant increases with Filtek Z350 and statistically significant decreases with each of Filtek Supreme Ultra and Ketac-Nano. Ketac-Nano showed statistically significant increases with all other composite materials using the same test (Table 8).

Comparing the means of the composite resin volume of the four groups before using the chewing simulator machine showed no statistically significant differences. This indicates that there was no difference in the volume of the compositre resin used in the four groups during sample preparation and variation in composite volumes before using the chewign simulator can be eliminated as confounder factor. This also indicates that the amount in volume loss found after using the chewing simulator machine is mostly due to differences in the types of materials used.

The 84.5%. study power result of the power calculation for One-way independent ANOVA indicated that this study has acceptable power with the provided sample size. The nature of almost fully automated 3D volume analysis in our study methodology could be a reasonable explanation of obtaining Pearson product-moment correlation coefficient high as 0.998. Computer automated analysis is often more accurate and thus more consistent result could be obtained.

The results were in line with those of Nayyer et al. (67). Both studies showed that Microhybrid resin composite (Filtek Z350) was higher in material hardness value compared to flowable composite. According to Nayyer et al, this may be because Filtek Z350 composite has increased filler content and greater filler particles surface area the flowable composite which has reduced filler loading (67).

Several studies compared Transbond XT hardness to flowable composite and conventional composite. Sifakakis et. al. found that Transbond XT was significantly higher in Martens hardness (HM), indentation modulus, and Vickers hardness (HV) values than the flowable composite. This agrees with our finding where Transbond XT significantly had less volume loss after chewing simulator testing than Filtek Supreme Ultra Flowable composite. According to their study, Transbond XT as well was significantly higher in Martens hardness (HM), indentation modulus, and Vickers hardness (HV) values than the IPS Empress Direct restorative composite. This finding was not in agreement with our study finding as in our study Transbond XT had significantly more volume loss than Microhybrid conventional resin composite (Filtek Z350). This disagreement could be related to the use of two different conventional composites. IPS Empress Direct is a nanohybrid direct dentin conventional restorative composite composed of UEDMA, TCDDMA, and BisGMA as resin matrix and Ba-Al-fluorosilicate (0.7 μm), ytterbium trifluoride (100 nm) and prepolymers (1–10 μm) as filler particles with 80% by weight of total fillers loading. IPS Empress Direct composition is different than the composition of Filtek Z350 used in our study (59).

In the current study, Ketac Nano which is a Resin Modified Glass Ionomer had the highest material volume loss among all the other materials tested. This finding is in agreement with several other studies. A study done by Correr et al. found that Resin Modified Glass Ionomer demonstrated the lowest resistance to wear among other conventional composite materials tested in their study. The relatively increased Resin Modified Glass Ionomer wear was suggested to be due to the properties of the material itself as the Resin Modified Glass Ionomer contains HEMA particles crosslinking between polyacid chains of the material. This HEMA crosslinking requires specific gaps between the two polyacid chains joined preventing them from being in closer contact. Therefore, the interaction of HEMA crosslinking with the polyacid chains could cause destabilizing and separation of the polyacid chains adequately to reduce the ionic interactions between the chains. Interruption of inter polyacid chains ionic interactions produces a glass ionomer material with less stiffness, hardness, and wear resistance. They also stated that Resin Modified Glass Ionomer has increased porosity, a larger size of the filler particles, reduced filler content, and inferior crosslinking between Resin Modified Glass Ionomer fillers and the resin matrix so that these could be another cause of increased wear of between Resin Modified Glass Ionomer (71).

The findings of the current study are in agreement with those of Viana et al. who compared material surface loss of Microhybrid resin composite (Filtek Z350) to Resin Modified Glass Ionomer (Fuji II LC). In their study, the Resin Modified Glass Ionomer showed increased material surface loss values after erosive test than Filtek Z350 composite similar to what we found in our study. They mentioned that the reason behind the increased wear of Resin Modified Glass Ionomer (Fuji II LC) is related to the greater water solubility. The increased solubility of the Resin Modified Glass Ionomer tend to dissolute the external lattice of silicate hydrogel in the glass particles structures causing the surface to be more prone to wear (68).

De Paula et al. conducted three-body abrasion test comparing surface roughness resistance and morphology changes between nanofilled composite 3M/ESPE Filtek Z350 and 3M/ESPE Ketac Resin Modified Glass Ionomer. The Filtek Z350 demonstrated a better resistance to surface roughness than 3M/ESPE Ketac Resin Modified Glass Ionomer. Our study showed the similar results. The former study stated that Filtek Z350 composite content of monomers with hydrophobic properties like Bis-EMA - ethoxylated bisphenol-A dimethacrylate most likely provided the material with more resistance to surface changes. Contrary, resin-modified glass ionomer content of of 2-hydroxyethyl methacrylate (HEMA), BisGMA and TEGDMA could cause the RMGI to have more surface wear.

In water, separation of Bis-GMA/HEMA occurs allowing the hydrophobic camphoroquinone to separate from hydrophobic Bis-GMA phase while tertiary amine hydrophilic end to leave the hydrophilic HEMA phase. This process lowers the affinity of Bis-GMA/HEMA connecting to each other leaving the Ketac matrix less levels of conversion setting reaction which in turn makes the RMGI less wear resistant (69).

Bansal et al. reported findings that are similar to our study. They compared surface wear of resin-modified glass-ionomer (RMGI) restorative material to a flowable resin composite (Filtek Supreme Ultra). Their results showed that flowable resin composite (Filtek Supreme Ultra) surface wear was significantly lower than resin-modified glass-ionomer (RMGI). The differences between these two materials in fillers loading and composition are the main reasons behind their finding (70).

In clinical application, fixed retainers should be bonded with conventional filling composite materials that containe high fillers content. highly filled composites seems to have better wear resistance and thus a higher fixed retainers survival rates could be achieved.

7.1 Limitations

Further clinical randomized trials will be needed to evaluate of the wear resistance of the composite materials in the real environment.

- This study didn’t use natural teeth.
- No thermal cycling to simulation of the oral cavity was done.
- The samples were not stored in artificial saliva or at 37 degree prior to testing.
- Surface hardness mesurment of the of the tested materials was not done.

7.2 Recommendations

Further randomized clinical trials are needed to test the wear resistance of retainer bonding materials. The employment of similar methodology using 3D models evaluation and analysis can help in clinical and laboratory future studies. For clinical appliacation, highly filled conventional filling composite materials are recommended to be used in fixed retainers bonding.

8. CONCLUSION

Composites fillers loading seems to affect their mechanical properties. Wear resistance values were significantly higher in composite with higher fillers content. While the lowest wear resistance values were found in materials with the least fillers content. Statistical differences in wear resistance were found between all the groups. The highest wear resistance was found with Filtek Z350 followed by Transbond XT, Filtek Supreme Ultra, while the lowest value was related to Ketac Nano. Further clinical trials with larger sample size will be needed to simulate the actual effect of the saliva and to simulate the oral environment.

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